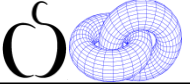


Трассировка лучей

Освещение. Текстурирование

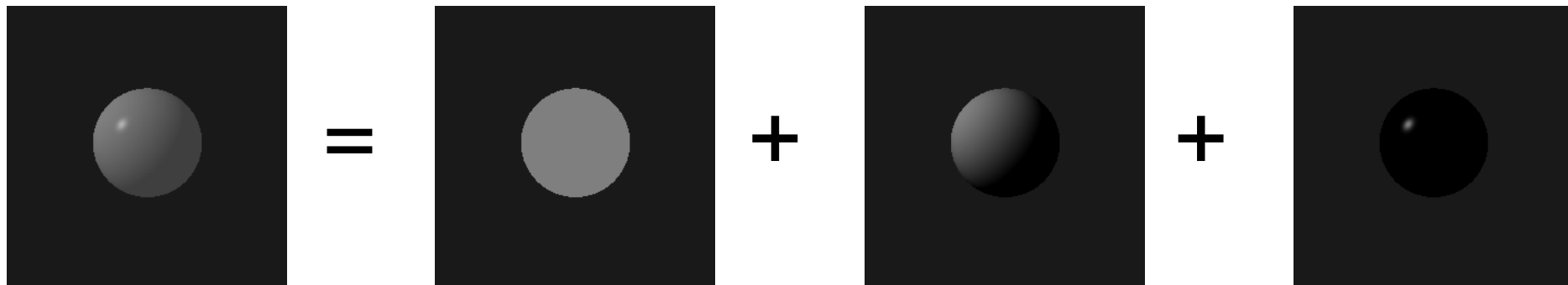
материалы занятий: <https://compsciclub.ru/courses/graphics2018/2018-autumn/classes/>

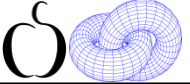
дублируются на сайте: <http://www.school30.spb.ru/cgsg/cgc2018/>



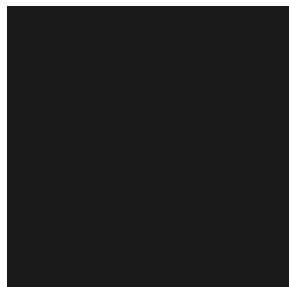
- Освещение=фоновое+диффузное+зеркальное

$$I_{\lambda} = I_{\lambda, Ambient} + I_{\lambda, Diffuse} + I_{\lambda, Specular}$$

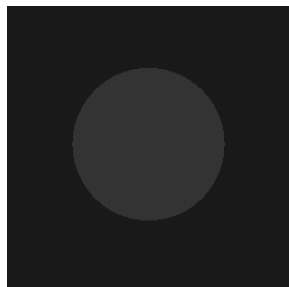




- K_A



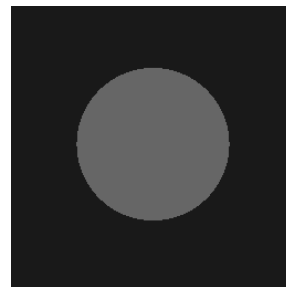
0.1



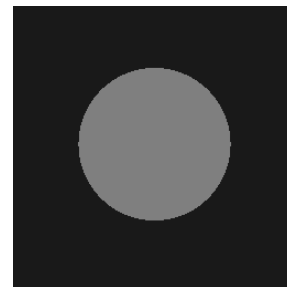
0.2



0.3

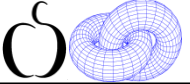


0.4

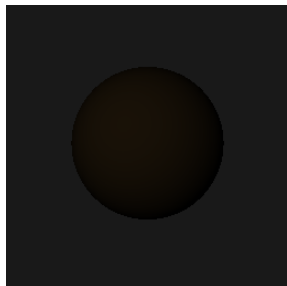


0.5

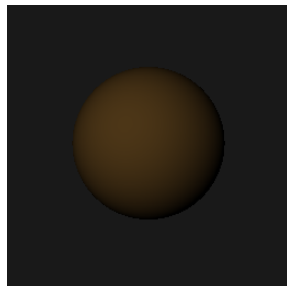
$$I_{\lambda,A} = I_{\lambda,A}^{Scene} \cdot K_{\lambda,A} \cdot I_{\lambda}^{Object}$$



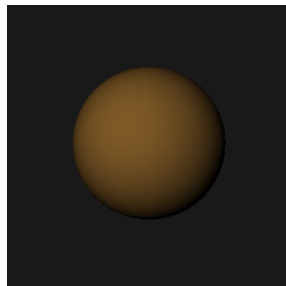
- K_D



0.1



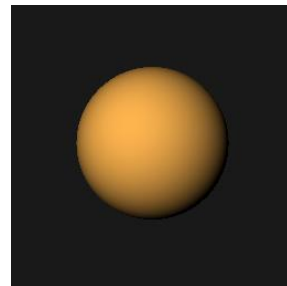
0.3



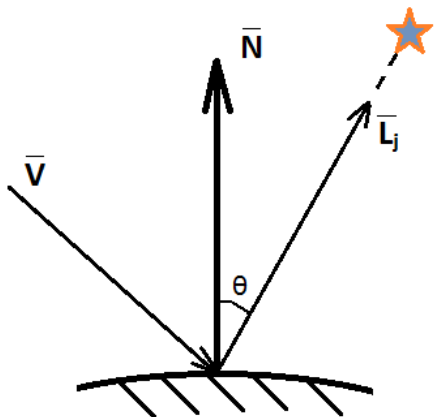
0.5



0.7

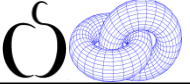


1.0

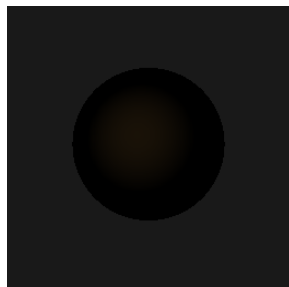


$$I_{\lambda,D} = K_{\lambda,D} \cdot I_{\lambda}^{Object} \cdot \sum_{j \text{ no u.c.}} I_{\lambda,Lj} \cdot (\cos \theta)$$

$$I_{\lambda,D} = K_{\lambda,D} \cdot I_{\lambda}^{Object} \cdot \sum_{j \text{ no u.c.}} I_{\lambda,Lj} \cdot (\vec{N} \cdot \vec{L}_j)$$



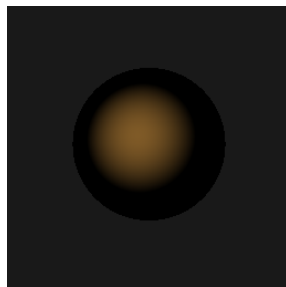
- K_S



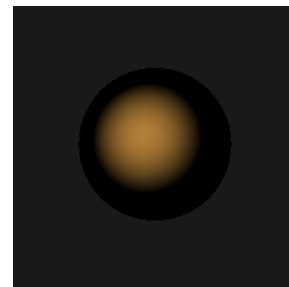
0.1



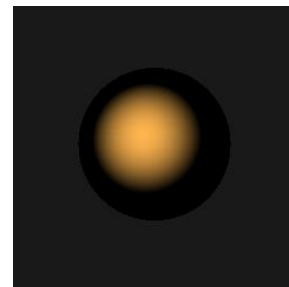
0.3



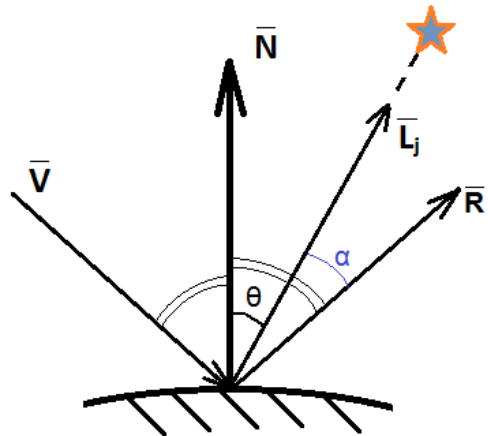
0.5



0.7

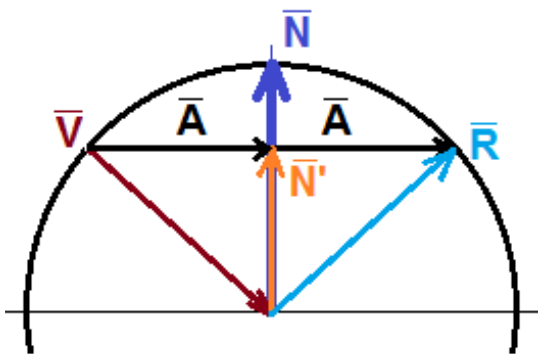


1.0



$$I_{\lambda,S} = K_{\lambda,S} \cdot \sum_{j \text{ no u.c.}} I_{\lambda,Lj} \cdot (\cos \alpha)^{Kp}$$

$$I_{\lambda,S} = K_{\lambda,S} \cdot \sum_{j \text{ no u.c.}} I_{\lambda,Lj} \cdot (\vec{R} \cdot \vec{L}_j)^{Kp}$$

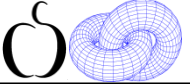


$$\vec{R} = -\vec{V} + \vec{A} \cdot 2$$

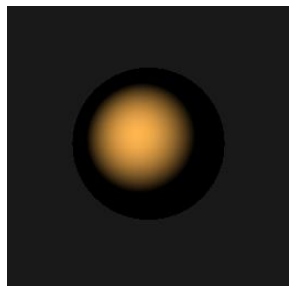
$$\vec{A} = \vec{V} + \vec{N}'$$

$$\vec{N}' = \vec{N} \cdot (-\vec{V} \cdot \vec{N})$$

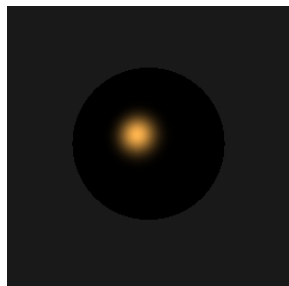
$$\begin{aligned} \vec{R} &= -\vec{V} + (\vec{V} + \vec{N} \cdot (-\vec{V} \cdot \vec{N})) \cdot 2 = \\ &= \vec{V} - \vec{N} \cdot 2 \cdot (\vec{V} \cdot \vec{N}) \end{aligned}$$



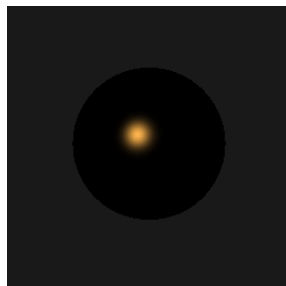
- K_p



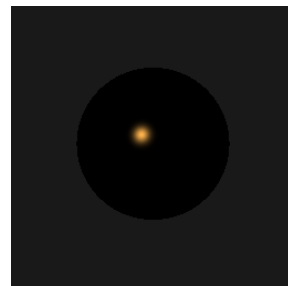
1



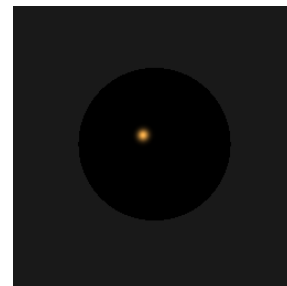
10



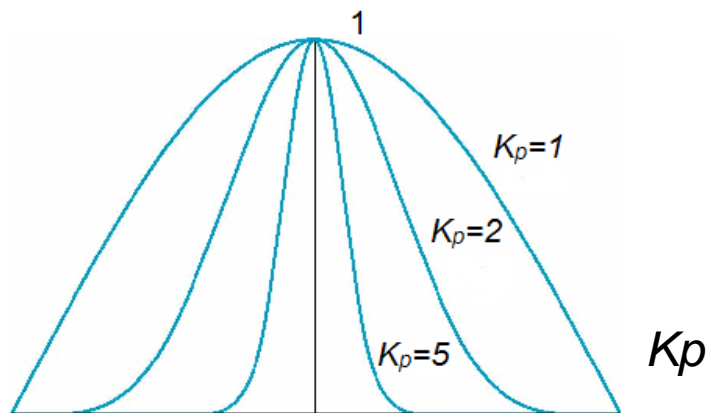
20

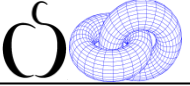


50

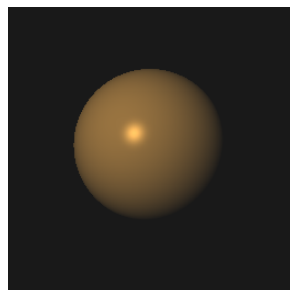
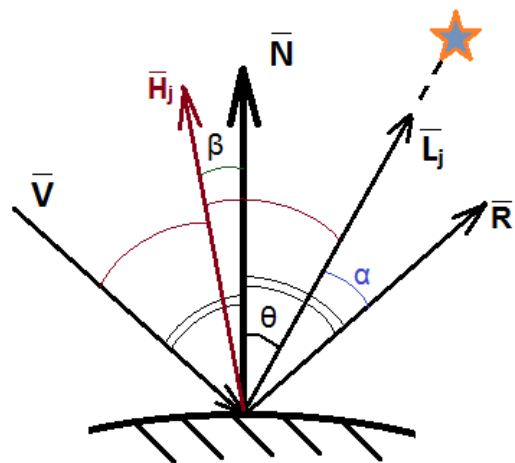


100

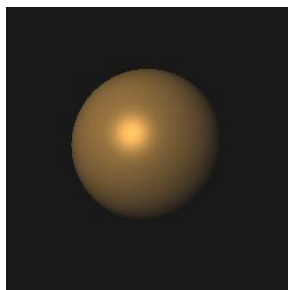




Модель Блинна-Фонга (Blinn-Phong)



R



H

 $K_A=0.1, K_D=0.5, K_S=0.8, K_D=36$

$$I_{\lambda,S} = K_{\lambda,S} \cdot \sum_{j \text{ no u.c.}} I_{\lambda,Lj} \cdot (\cos \alpha)^{Kp}$$

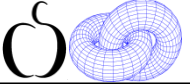
$$I_{\lambda,S} = K_{\lambda,S} \cdot \sum_{j \text{ no u.c.}} I_{\lambda,Lj} \cdot (\vec{R} \cdot \vec{L}_j)^{Kp}$$

$$\vec{H}_j = \frac{-\vec{V} + \vec{L}_j}{|-\vec{V} + \vec{L}_j|}$$

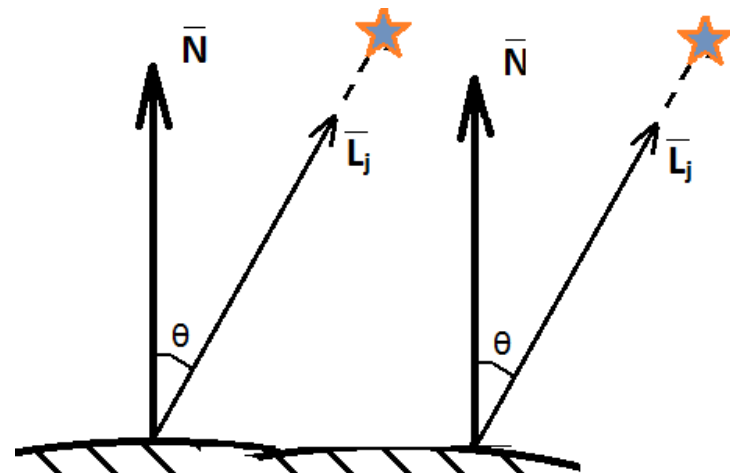
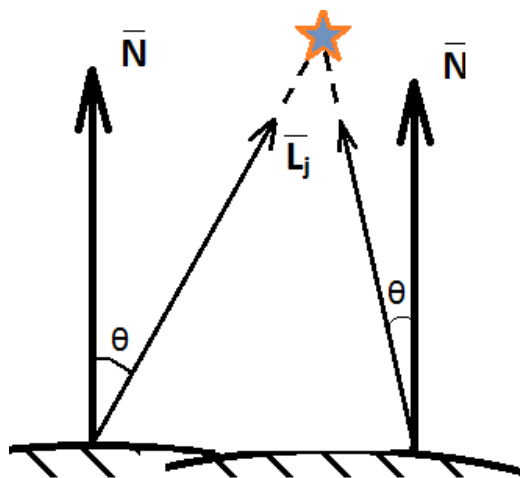
$$I_{\lambda,S} = K_{\lambda,S} \cdot \sum_{j \text{ no u.c.}} I_{\lambda,Lj} \cdot (\cos \beta)^{Kp}$$

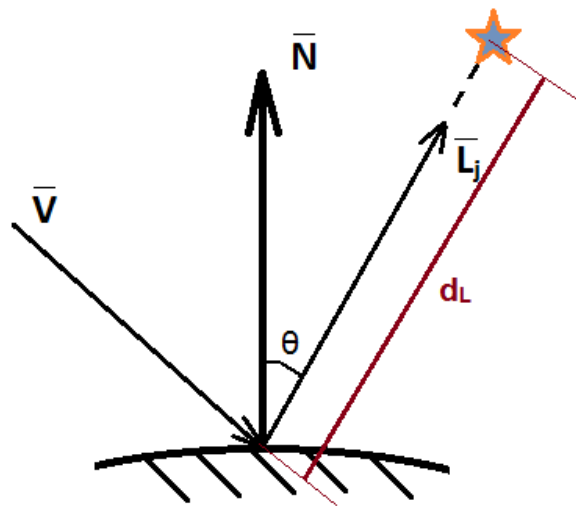
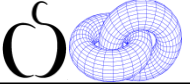
$$I_{\lambda,S} = K_{\lambda,S} \cdot \sum_{j \text{ no u.c.}} I_{\lambda,Lj} \cdot (\vec{N} \cdot \vec{H}_j)^{Kp}$$





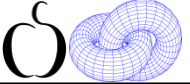
Точечные (фиксируется позиция) Направленные (фиксируется направление)



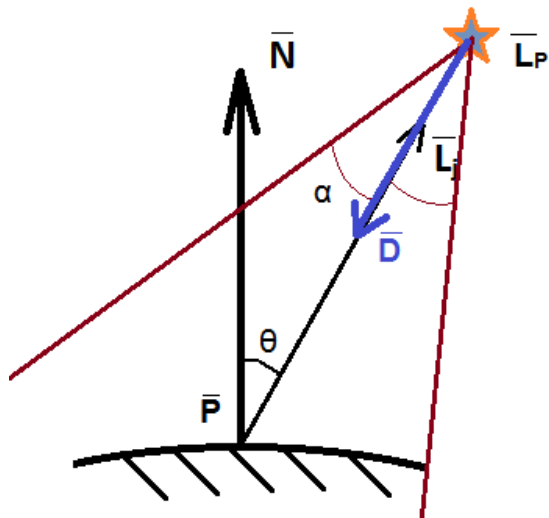


$$I_{\lambda} = I_{\lambda, Ambient} + \sum_{j \text{ no u.c.}} F_{j, att} \cdot (I_{\lambda, Diffuse} + I_{\lambda, Specular})$$

$$F_{j, att} = \min \left(\frac{1}{C_C + C_L \cdot d_L + C_Q \cdot d_L^2}, 1 \right)$$

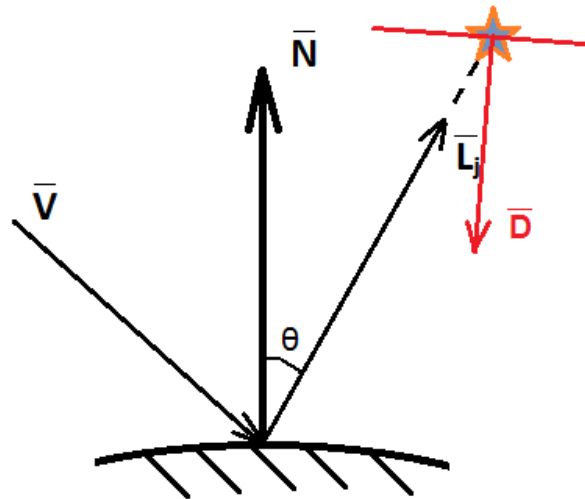


Заслонки (прожектор)

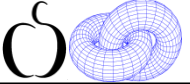


если $(-\vec{L}_j \cdot \vec{D}) > \cos \alpha$ то $F_{j,att} = 1$
иначе $F_{j,att} = 0$

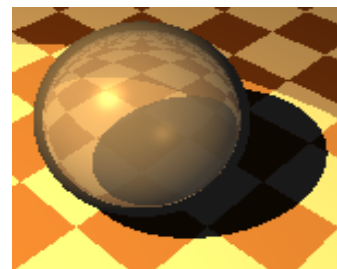
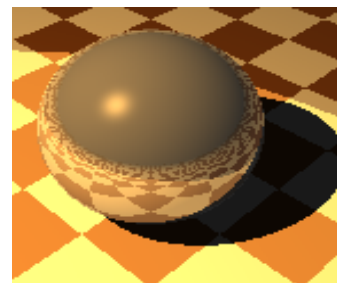
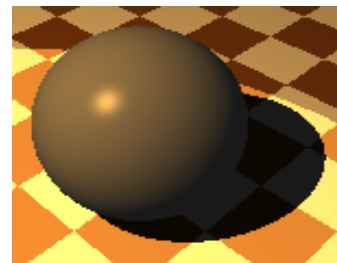
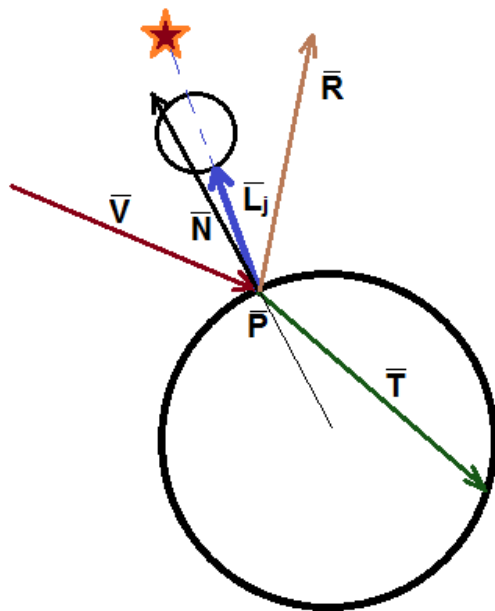
Рефлекторы



$$F_{j,att} = \max(-\vec{L}_j \cdot \vec{D}, 0)$$



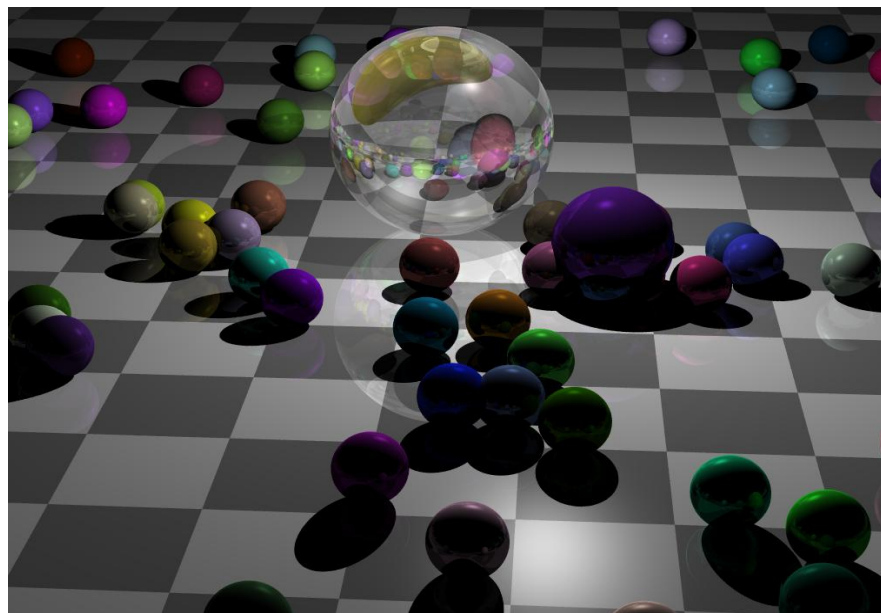
- Тени
- Отражение
- Преломление
- Туман
- Рекурсия

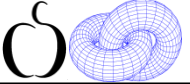


$$Trace(ray(\vec{P}, \vec{L}_j))$$

если пересечений нет $F_{j,att} = 1$

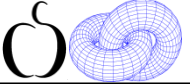
иначе $F_{j,att} = 0$



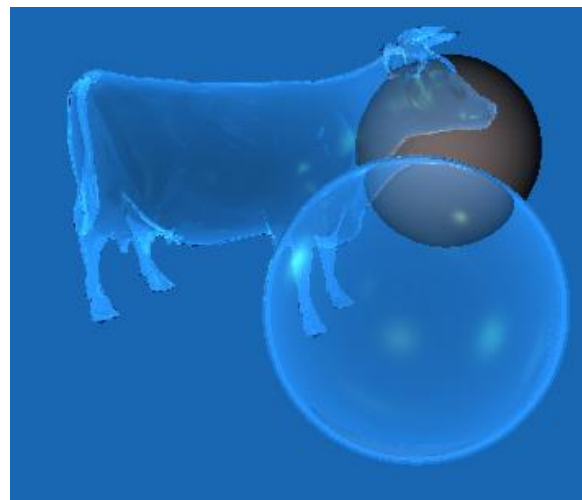
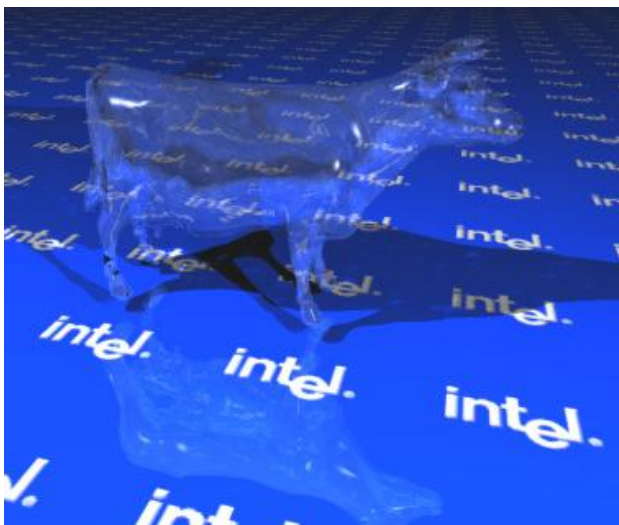


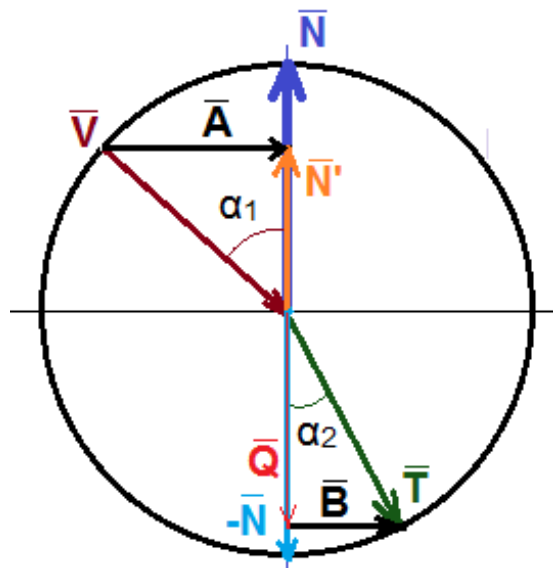
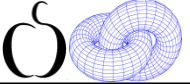
$$I_{\lambda, \text{reflected}} = K_{\lambda, S} \cdot \text{Trace}_{\lambda}(\text{ray}(\vec{P}, \vec{R})) \cdot e^{-\beta \cdot d_r}$$





$$I_{\lambda,transmitted} = K_{\lambda,T} \cdot Trace_{\lambda}(ray(\vec{P},\vec{T})) \cdot e^{-\beta \cdot d_t}$$





$$\frac{\eta_1}{\eta_2} = \frac{\sin \alpha_1}{\sin \alpha_2}$$

$$\vec{T} = \vec{Q} + \vec{B}$$

$$\vec{Q} = -\cos \alpha_2 \cdot \vec{N} = -\sqrt{1 - \sin^2 \alpha_2} \cdot \vec{N} =$$

$$= -\sqrt{1 - \sin^2 \alpha_1 \cdot \frac{\eta_2^2}{\eta_1^2}} \cdot \vec{N} = -\sqrt{1 - (1 - \cos^2 \alpha_1) \cdot \frac{\eta_2^2}{\eta_1^2}} \cdot \vec{N}$$

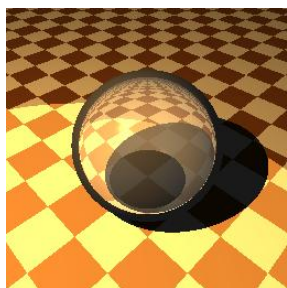
$$\vec{B} = \frac{\sin \alpha_2}{\sin \alpha_1} \cdot \vec{A} = \frac{\eta_2}{\eta_1} \cdot \vec{A} = \frac{\eta_2}{\eta_1} \cdot (\vec{V} - \vec{N} \cdot (\vec{V} \cdot \vec{N}))$$

$$\eta = \frac{\eta_2}{\eta_1}$$

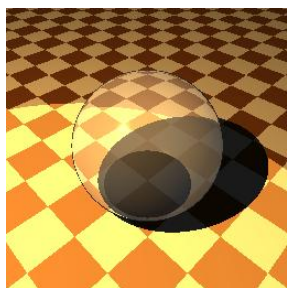
$$\vec{T} = \eta \cdot (\vec{V} - \vec{N} \cdot (\vec{V} \cdot \vec{N})) - \sqrt{1 - (1 - \cos^2 \alpha_1) \cdot \frac{\eta_2^2}{\eta_1^2}} \cdot \vec{N}$$



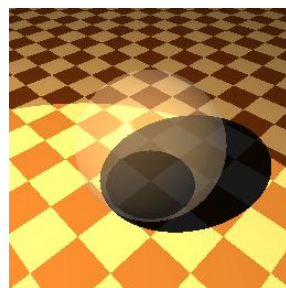
• η



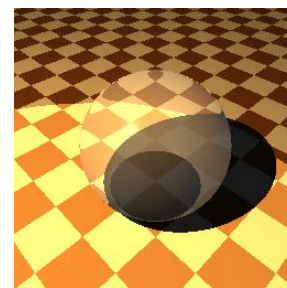
1.1



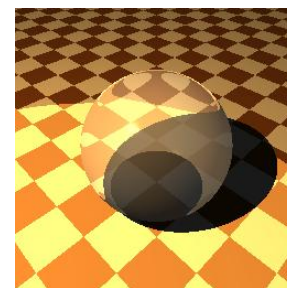
1.01



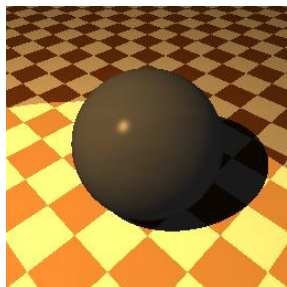
1.0



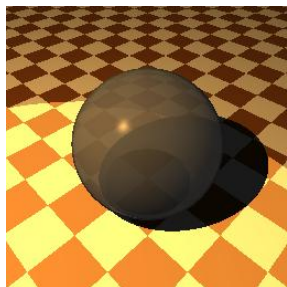
0.99



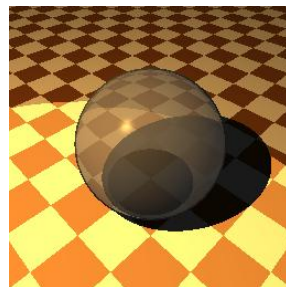
0.98



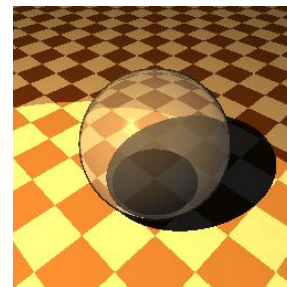
0.1



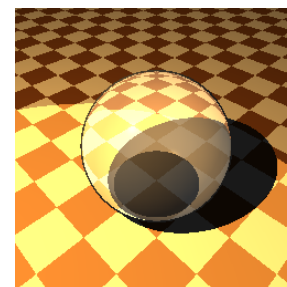
0.3



0.5



0.7

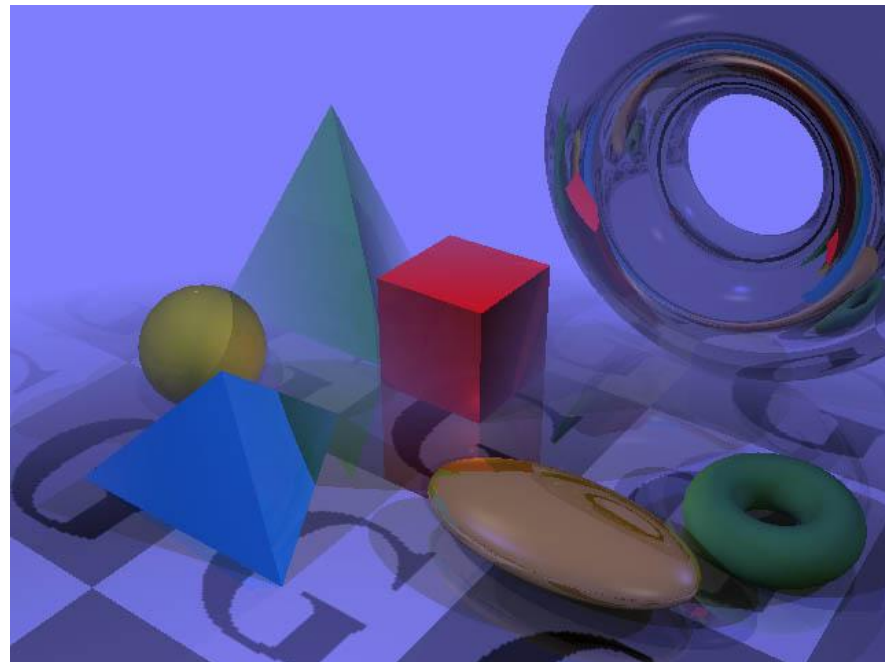


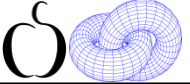
1.0

$$fog = e^{-density \cdot d_{ray}}$$

$$fog = \begin{cases} 1, & d_{ray} < start \\ \frac{d_{ray} - start}{end - start} & \\ 0, & d_{ray} > end \end{cases}$$

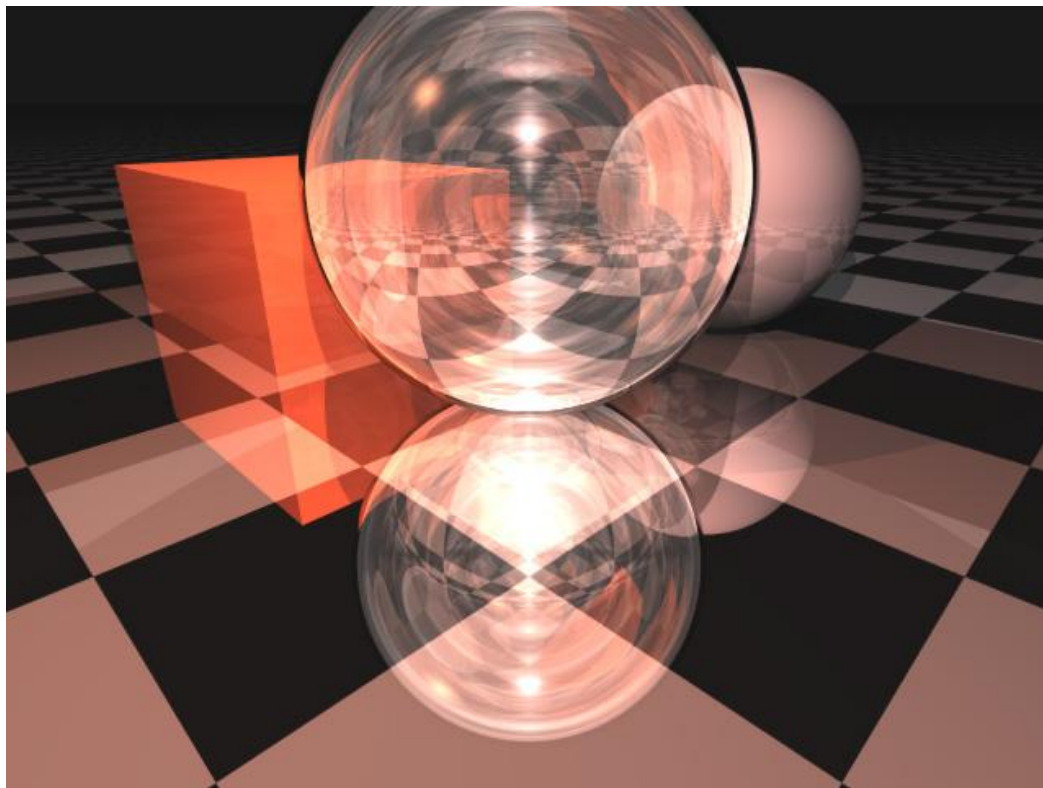
$$I_{\lambda} = I_{\lambda, traced} \cdot fog + I_{\lambda}^{fog} \cdot (1 - fog)$$

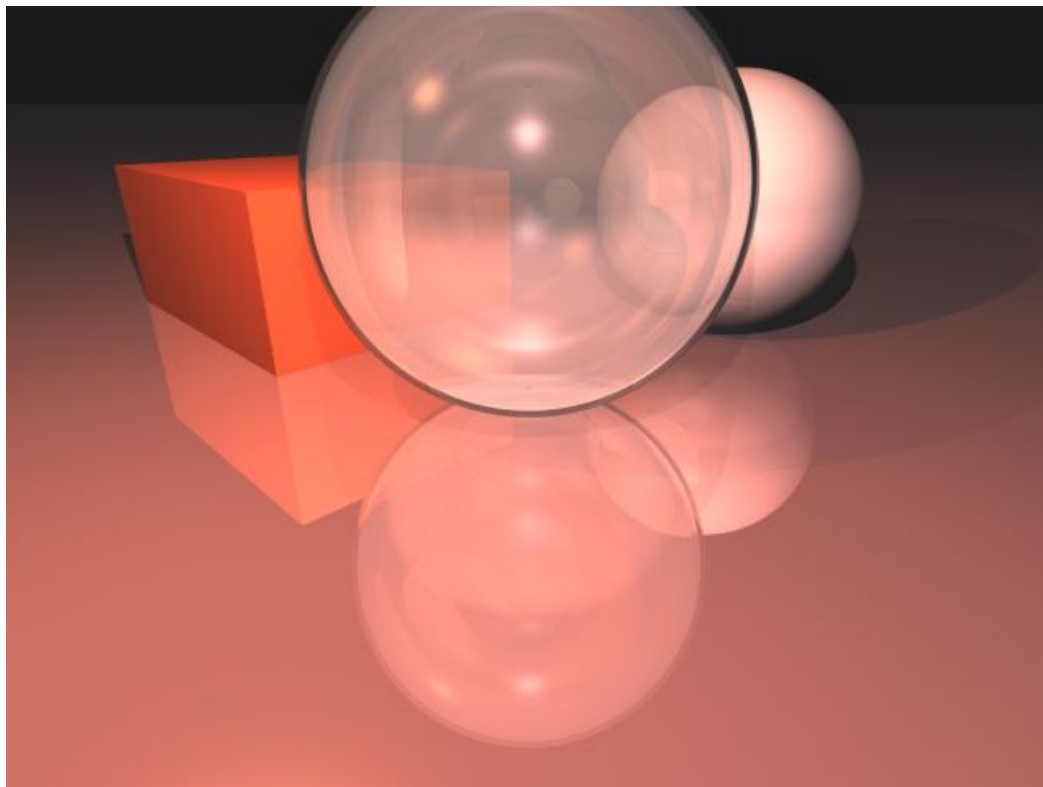
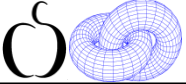


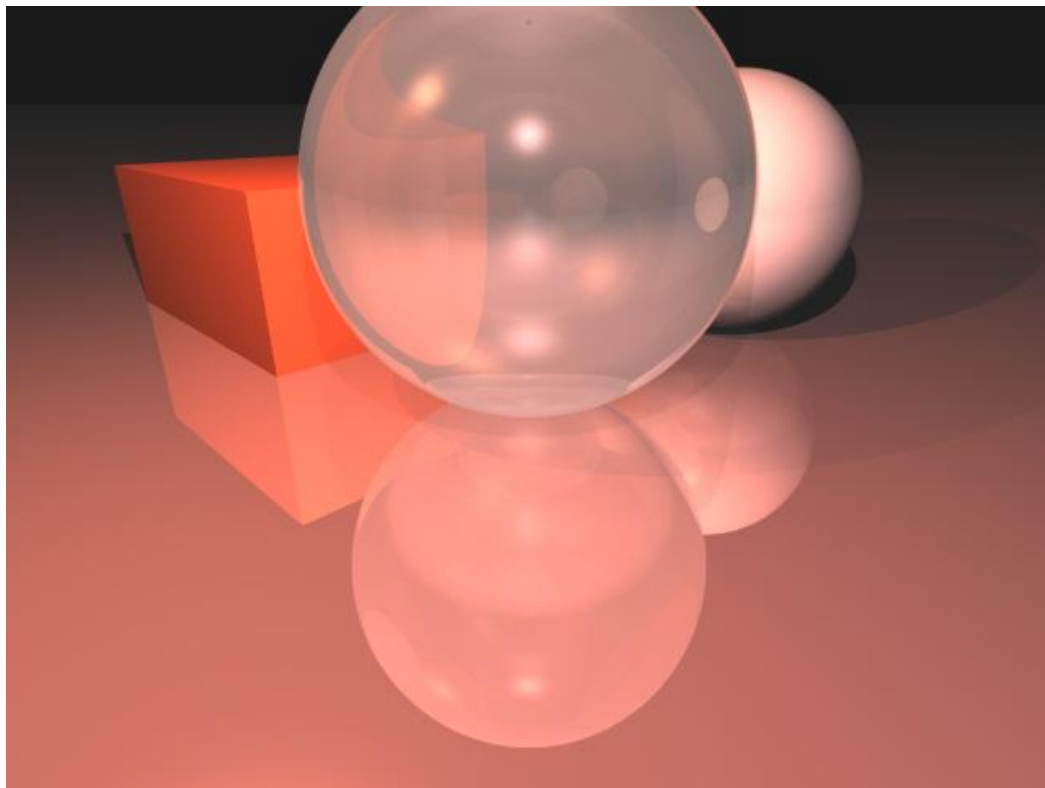
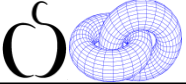


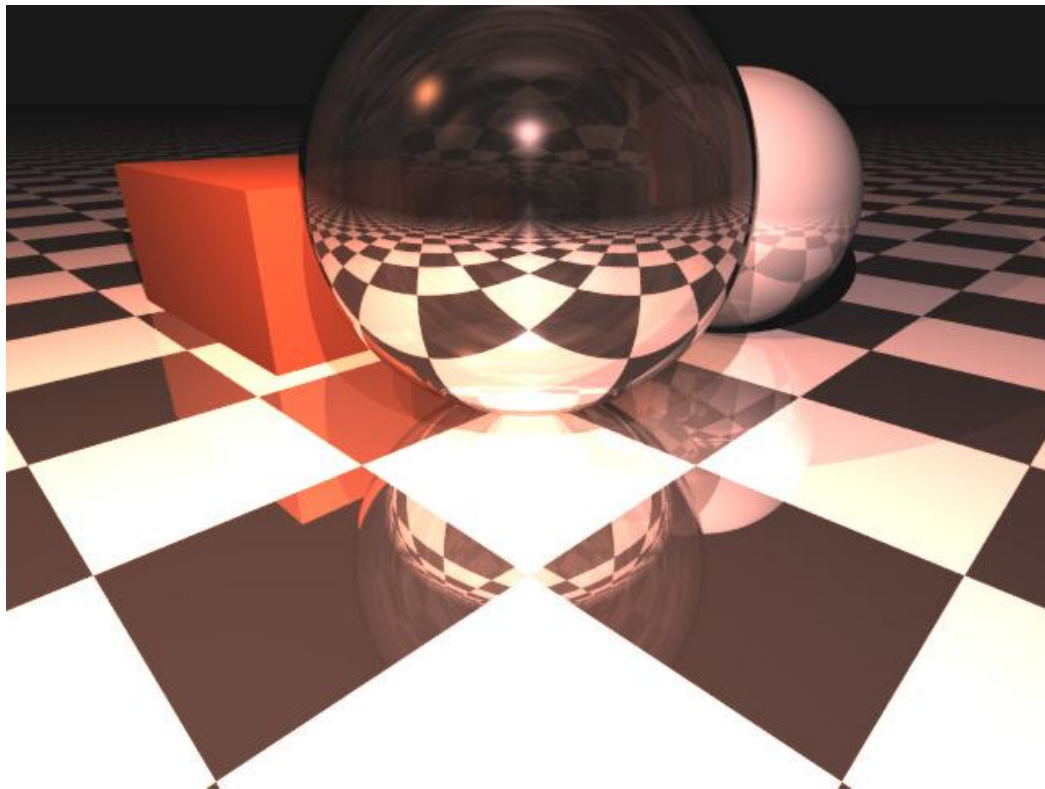
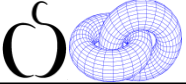
$$\begin{aligned} I_{\lambda} = & I_{\lambda,A}^{Scene} \cdot K_{\lambda,A} \cdot I_{\lambda}^{Object} + \\ & I_{\lambda}^{Object} \cdot \sum_{j \text{ no u.c.}} F_{j,att} \cdot \left(K_{\lambda,D} \cdot I_{\lambda,Lj} \cdot (\vec{N} \cdot \vec{L}_j) + K_{\lambda,S} \cdot I_{\lambda,Lj} \cdot (\vec{R} \cdot \vec{L}_j)^{Kp} \right) + \\ & K_{\lambda,S} \cdot Trace_{\lambda}(\text{ray}(\vec{P}, \vec{R})) \cdot e^{-\beta \cdot d_r} + K_{\lambda,T} \cdot Trace_{\lambda}(\text{ray}(\vec{P}, \vec{T})) \cdot e^{-\beta \cdot d_t} \end{aligned}$$

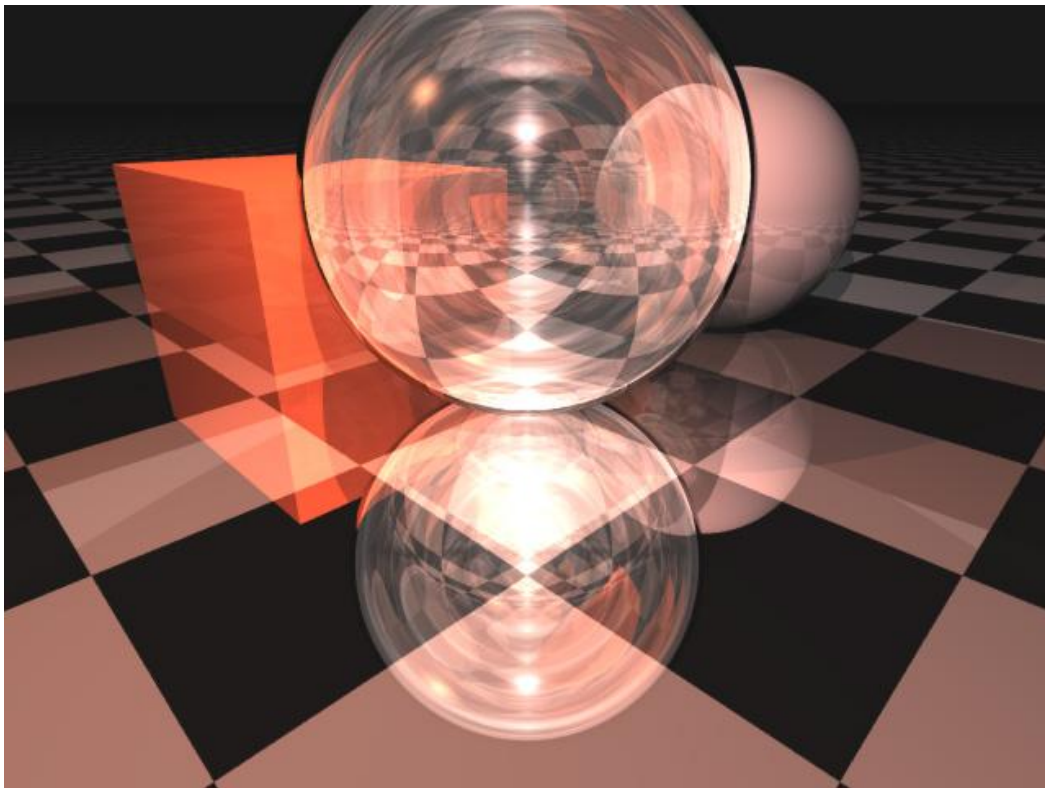
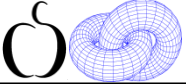


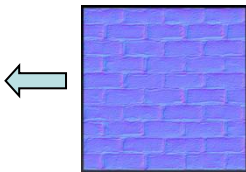
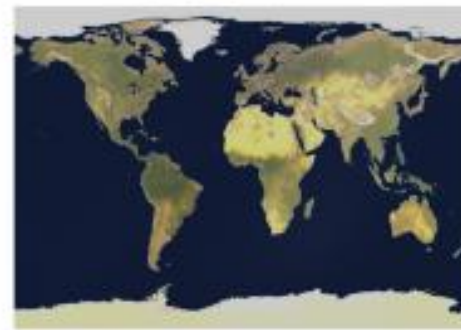


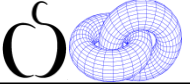




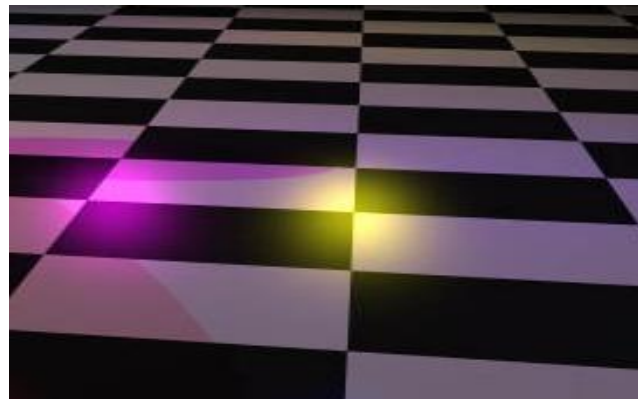






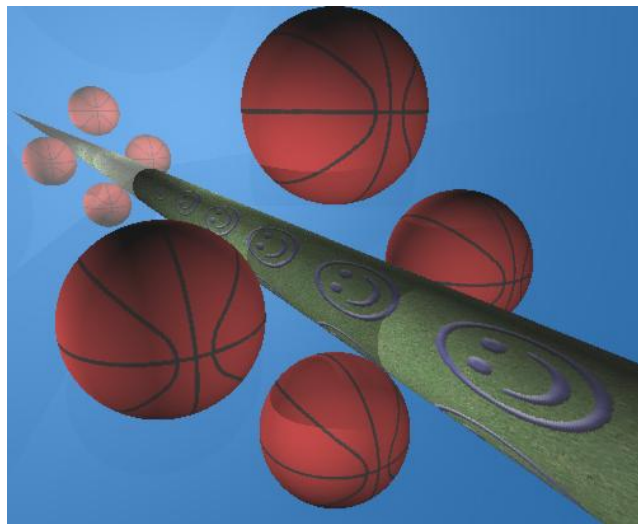


$$(u, v) = (x, y)$$

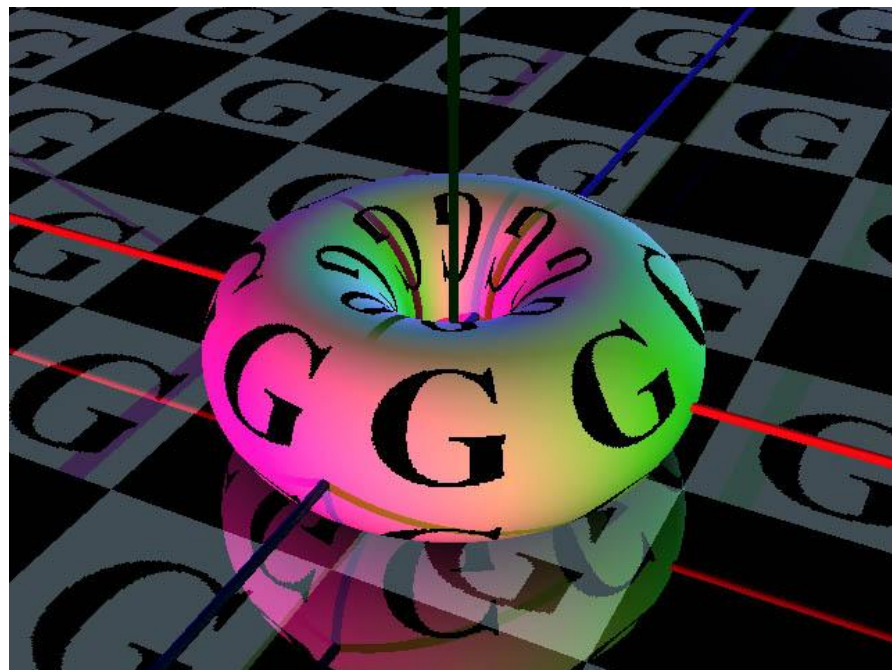


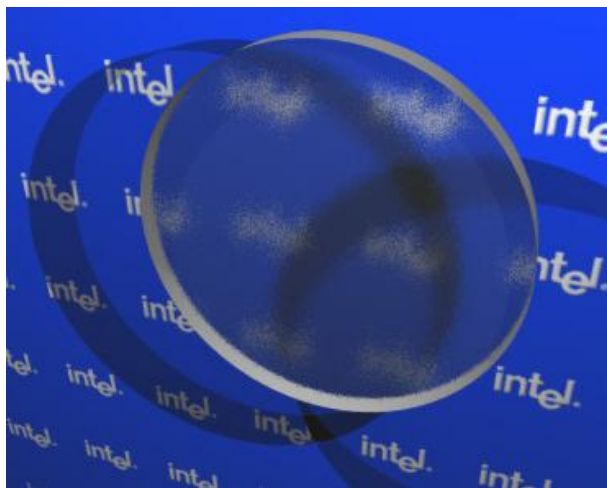
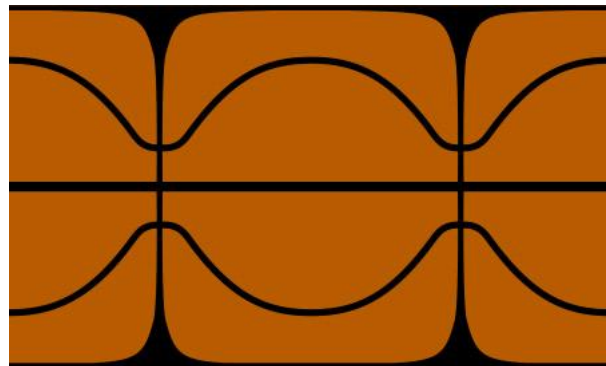
$$(u, v) = \left(\text{atan2}(x, z), \text{acos}\left(\frac{y}{\sqrt{x^2 + z^2}}\right) \right)$$

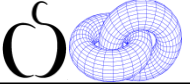




$$(u, v) = \left(\text{atan2} \left(\frac{x}{\sqrt{x^2 + y^2}}, \frac{z}{\sqrt{x^2 + y^2}} \right), \sqrt{x^2 + y^2} \right)$$



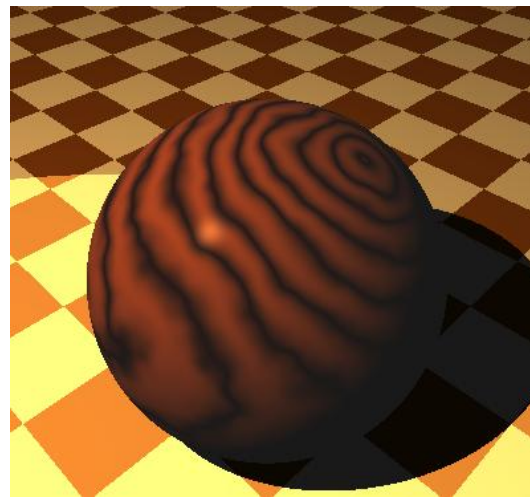
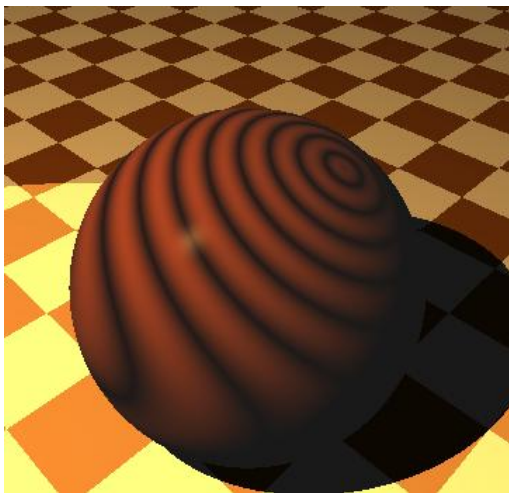


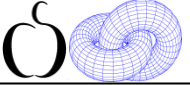


$$C(x, y, z) = C_1 + (C_1 - C_2) \cdot f\left(\sqrt{x^2 + y^2}\right)$$

$$f(a) = \frac{1 + \sin a}{2}$$

$$f(a) = \left(\frac{1 + \sin(a + \text{noise}(x, y, z))}{2} \right)^p$$





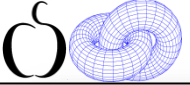
```
#define TAB_BITS 10
#define TAB_SIZE (1 << TAB_BITS)
#define TAB_MASK (TAB_SIZE - 1)

/* Noise table */
double TabNoise[TAB_SIZE];

double Noise( double X )
{
    int ix, ix1;
    double fx;

    ix = floor(X);
    fx = X - ix;
    fx = (3 - 2 * fx) * fx * fx;
    ix &= TAB_MASK;
    ix1 = (ix + 1) & TAB_MASK;
    return TabNoise[ix] * (1 - fx) + TabNoise[ix1] * fx;
} /* End of 'Noise' function */
```





```
/* Noise table parameters (size and mask) */
#define TAB_BITS 10
#define TAB_SIZE (1 << TAB_BITS)
#define TAB_MASK (TAB_SIZE - 1)

#define INDEX1(X) (Perm[(X) & TAB_MASK])
#define INDEX2(X, Y) INDEX1((X) + INDEX1(Y))
#define INDEX3(X, Y, Z) INDEX2(X, INDEX2(Y, Z))
#define INDEX4(X, Y, Z, W) INDEX3(X, Y, INDEX2(Z, W))

/* Noise table */
double TabNoise[TAB_SIZE];

/* Permutation table */
int Perm[TAB_SIZE];
```

```
double Turb( double X, int Octave )
{
    double sum = 0, frac = 1, norm = 0;

    for (int i = 0; i < Octave; i++)
    {
        sum += Noise(X) / frac;
        norm += 1 / frac;
        X = (X + 0.30) * 2;
        frac *= 2;
    }
    return sum / norm;
} /* End of 'Turb' function */
```

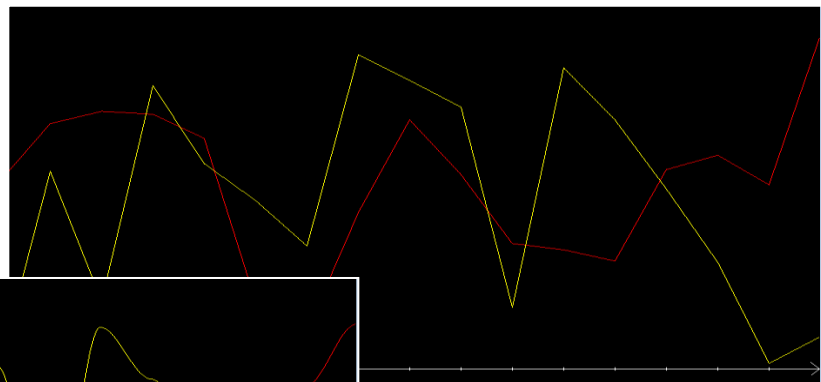
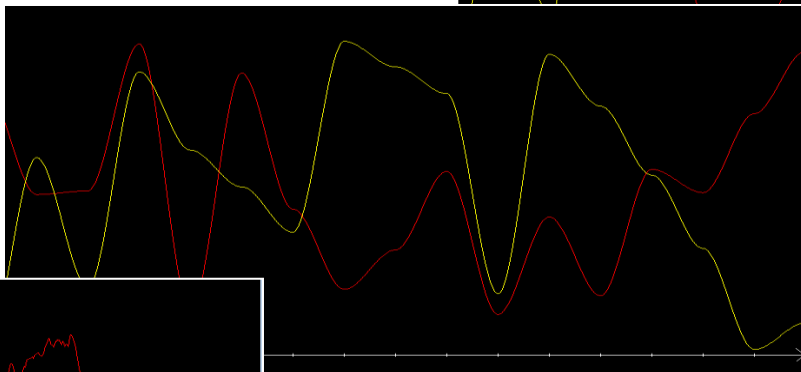
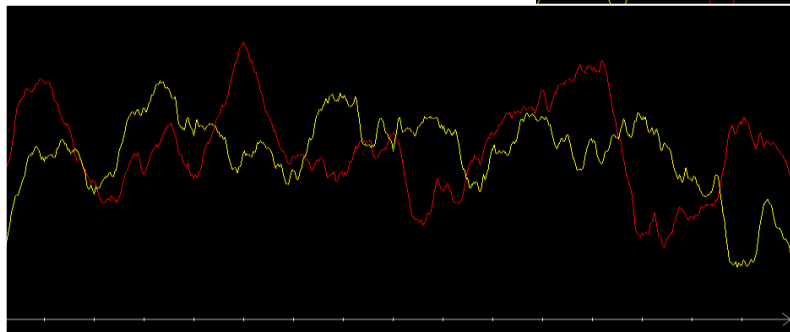
Noise1D:

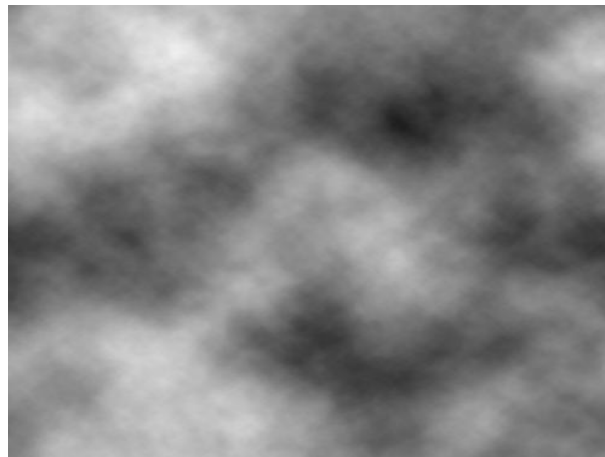
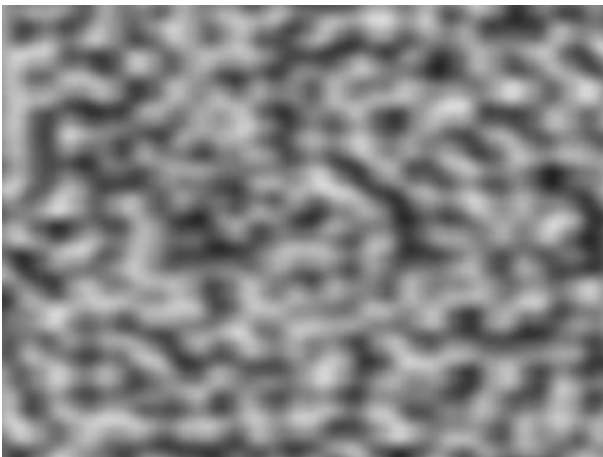
```
...
return TabNoise[INDEX1(ix)] * (1 - fx) +
       TabNoise[INDEX1(ix1)] * fx;
```

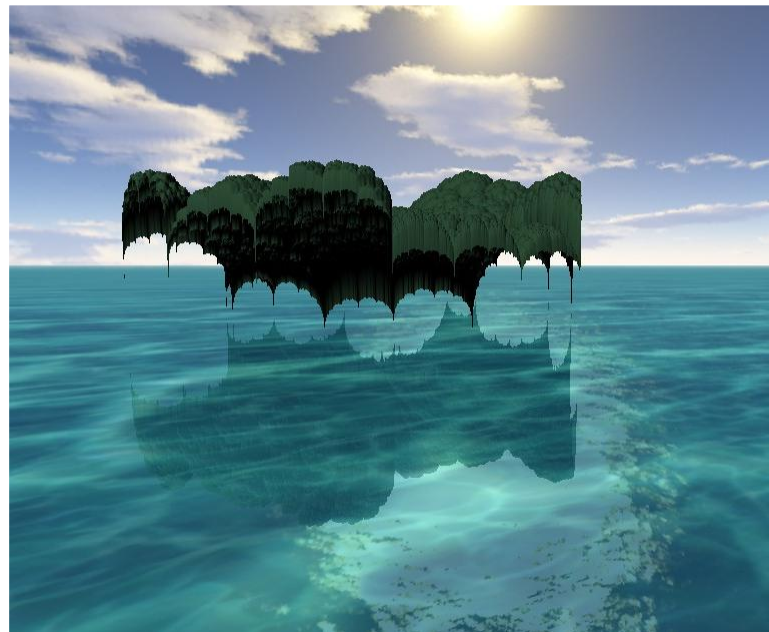
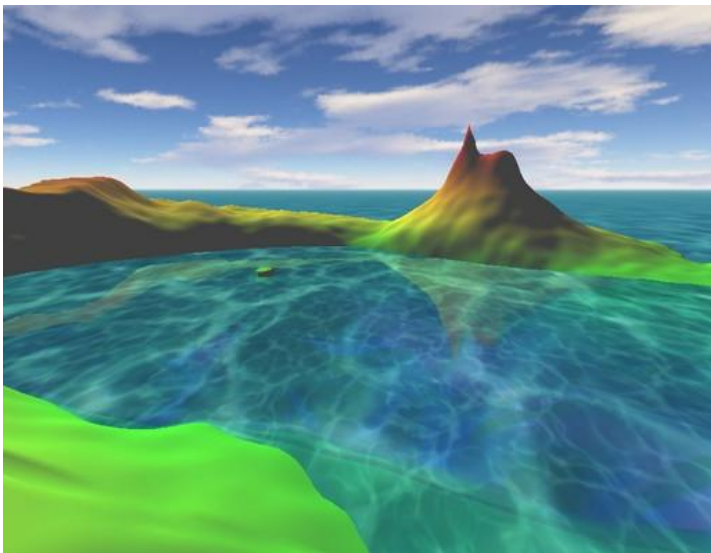
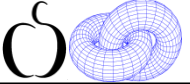
Noise2D:

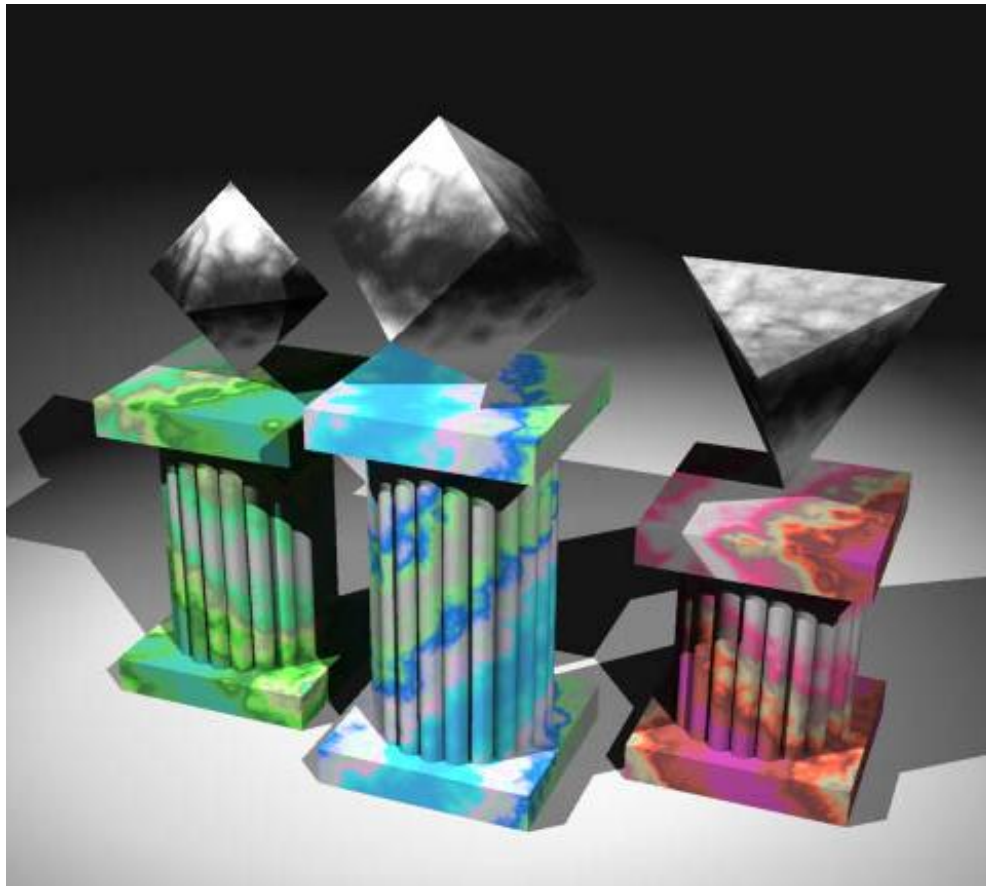
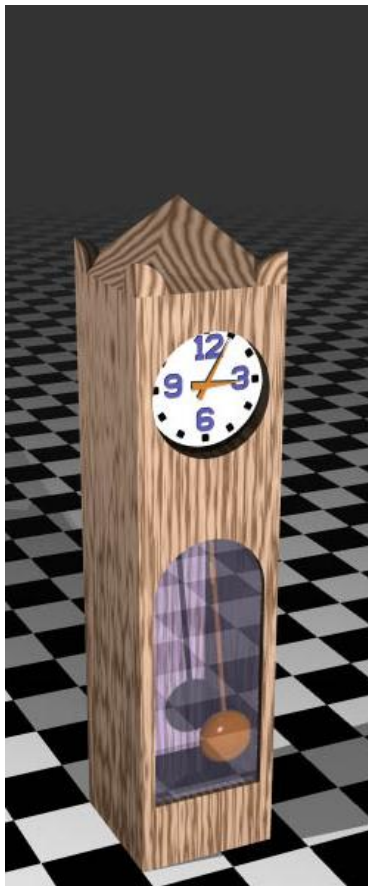
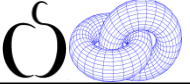
```
...
return
    TabNoise[INDEX2(ix, iy)] * (1 - fx) * (1 - fy) +
    TabNoise[INDEX2(ix1, iy)] * fx * (1 - fy) +
    TabNoise[INDEX2(ix, iy1)] * (1 - fx) * fy +
    TabNoise[INDEX2(ix1, iy1)] * fx * fy;
```

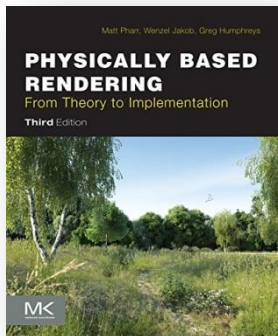




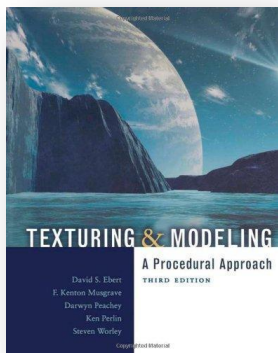








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